Mediterranean Drifter Data Analyses

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LONG-TERM GOALS

To contribute to the understanding of the dynamics of marginal seas such as the Mediterranean by collecting and interpreting accurate Lagrangian observations of currents and satellite measurements of water mass properties (e.g., temperature, salinity, chlorophyll concentration). In particular, to study the variability of the surface velocity and temperature/chlorophyll fields in selected basins of the Mediterranean at the meso-, seasonal and interannual scales and to assess the impact of the wind forcing and fresh water runoffs.

OBJECTIVES

1) To quantify the instrumental and sampling errors associated with velocity statistics derived from Lagrangian data sets. In particular, to assess the water-following characteristics of commonly-used surface drifters by making direct measurements of the relative flow around their body under various wind and wave conditions. To use advection-diffusion statistical models of trajectory prediction to estimate important sampling errors, such as the so-called "array" bias affecting the estimated mean flow. To find design criteria for optimizing drifter deployment strategies.

2) To describe the spatial characteristics and the temporal evolution of the surface circulation, the sea surface temperature (SST) and the surface chlorophyll concentration in selected basins of the Mediterranean, e.g., in the Ionian Sea, from meso- to interannual scales. To investigate some aspects of the response of the surface circulation and SST/chlorophyll to atmospheric (e.g., winds) and boundary (e.g., river runoffs) forcings. In particular, to study the characteristics of wind-driven currents (i.e., upwelling events).

APPROACH

1) Direct measurements of the relative water flow around surface drifters in various wave and wind conditions. Interpretation of the measurements using multi-variate regression analyses to find simple models of drifter slip versus wind speed and direction and versus wave significant height and direction.

2) Estimation of Lagrangian sampling errors, and in particular of the important "array" bias error, using statistical models. Assessment of the validity of Davis (1999)'s formula using numerically simulated drifter trajectories produced by a "random flight" model (Gaussian-Markov process). The use of the

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same model to seek an optimized drifter deployment strategy to map the mean flow and eddy variability and to quantify particle dispersion (Lagrangian statistics).

3) The analysis and interpretation of historical Ionian surface drifter data sets collected between 1990 and 1999 by various organizations, mostly by the SACLANT Undersea Research Centre (SACLANTCEN), by the Naval Oceanographic Office (NAVOCEANO) and by the Naval Postgraduate School (NPS). Eulerian and Lagrangian statistics of the Ionian surface circulation and SST are computed. Sampling random and bias errors on the mean flow estimates are estimated.

4) The use of satellite images concurrently with the drifter data to describe the variability of the surface currents, SST and surface chlorophyll fields in coastal areas of the Ionian Sea (Strait of Sicily and of Otranto, near the Cretan islands and along the African coast). AVHRR images archived by SACLANTCEN and processed by the Satellite Oceanography Laboratory of the University of Hawaii (Dr. P. Flament) are used to study the SST variability. SeaWiFS images downloaded from the Goddard DAAC are utilized to create maps of surface chlorophyll concentration during periods of large drifter concentration.

WORK COMPLETED

1) Drifter Tests in the Northern Adriatic Sea

Two commonly-used surface drifters, the CMOD (without case) and the CODE, and a new drifter design (MICROSTAR) were equipped with acoustic velocimeters and with GPS receivers, without changing significantly their hydro-dynamical characteristics (e.g., size, buoyancy and drag area). These prototype drifters were deployed in the vicinity of the "Acqua Alta" oceanographic tower off Venice on 6 and 8 November 2001 and on 2 and 3 April 2002. They remained in the water for 1-6 hours each day. Pressure gauges at the tower provided significant wave height and wave direction data. The ship used for the deployment/recovery operations was fitted with a meteorological station to collect wind data close to the drifters. Wind speeds varied between 0 and 6 m/s and the significant wave heights ranged in 0-0.33 m.

On 4 and 5 April 2002 sea conditions prevented operations with the ship. The CODE prototype drifter attached with a long rope was deployed directly from the oceanographic tower (see Fig. 1). It was left in the water for about 10 minutes until tension was evident on the rope, after which it was pulled back near the platform. These operations were repeated 36 and 12 times on 4 and 5 April, respectively. Wind speeds at the tower when the drifters were in water ranged in 0 - 15 m/s whereas significant wave heights varied between 0.37 and 1.44 m.

2) Drifter Deployment strategies applied to the Adriatic Sea

A statistical numerical model based on Langevin equation ("random flight" model) was used to find optimized drifter deployment strategies in the northern and middle Adriatic. This model uses the statistics inferred from the historical Adriatic drifter data base spanning 1990 –1999. In practice, the numerical drifters are integrated using a constant Eulerian mean velocity field plus a time-varying fluctuating component in which the characteristics of the variability ellipses and the Lagrangian

integral time scale are considered. A total of 100 ensembles (or realizations) of more than 120 drifter tracks integrated up to 150 days have been produced.

Fig. 1. Prototype CODE drifter being deployed from the "Acqua Alta" oceanographic tower on 4 April 2002 in wind speeds of about 15 m/s and with significant wave heights of 1.4 m.

RESULTS

1) Drifter tests in the Northern Adriatic Sea

Regression were performed between the 10-min (or 5-min) averaged relative flow data and the wind observations using all the data collected by the prototype CODE drifters in the northern Adriatic (in March and November 2001 and in April 2002) (see Fig. 2). Observations were averaged in 1 m/s wind speed bins. It was found that the slip of the CODE drifter increases with wind speed with a slope of about 0.12%. In the cross-wind direction the slip increases like 0.08% of the wind speed (to the right). So it can be concluded that the CODE drifter slips downwind and to the right of the wind, and that the magnitude of this slip remains bounded by 2 cm/s for wind speeds up to 15 m/s.

2) Drifter Deployment strategies applied to the Adriatic Sea

After some trial and error tests, specific deployment locations for the 120 drifters were found to yield a good continuous sampling of the northern and middle Adriatic for about a year. Fig. 3 shows some of the results obtained with the numerical drifter tracks calculated with the mean Eulerian velocity field only.

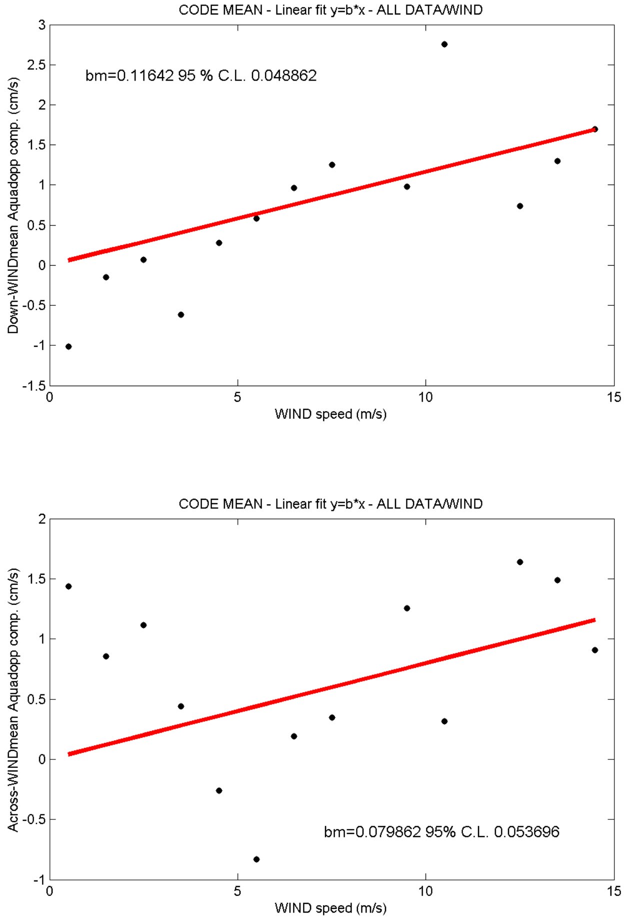

Fig. 2. Mean down-wind (top) and cross-wind (bottom, positive to the right) slip speeds versus wind speed measured for the CODE drifter in the Northern Adriatic (March and November 2001 and April 2002). Mean slips were obtained by averaging the relative flow measured by the Aquadopp velocimeter at the top and at the bottom of the drifter. Observations were then averaged in bins of 1 m/s wind speed.

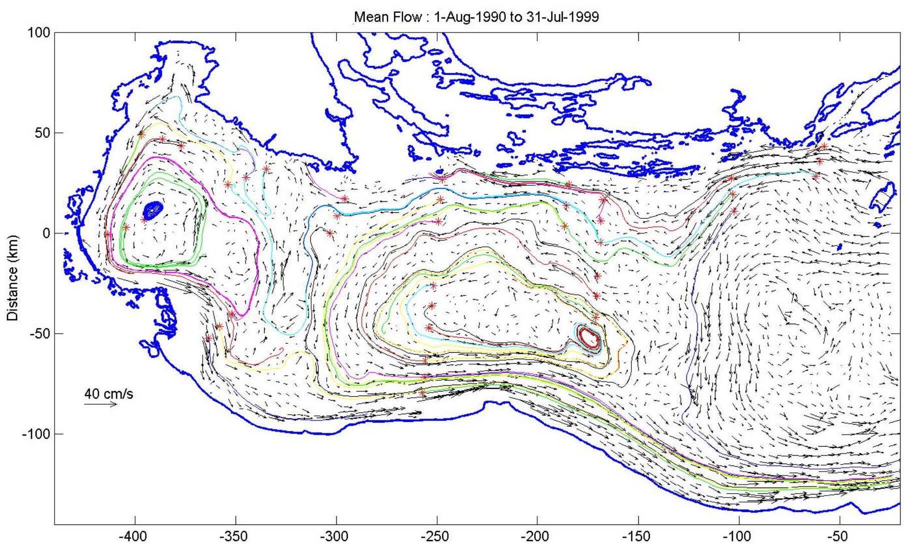

Fig. 3. Mean circulation map in the northern and middle Adriatic calculated from drifter data in 1990-1999. Examples of numerical tracks (in this case using only advection by the mean flow) are overlaid.

IMPACT/APPLICATION

The scientific impact of this project will be to increase our understanding of the Mediterranean dynamics and of the major forcing mechanisms. Future application could be the assimilation of the drifter data into numerical models in the framework of the upcoming Mediterranean Forecasting System (MFSTEP). The assessment of the water-following capabilities of the surface drifters is important for future drifter experiments, e.g., the Lagrangian component of the ONR-sponsored DOLCEVITA project planned in 2002-2003.

TRANSITIONS

This program quantifies the water-following characteristics of the drifters that NAVOCEANO has been (and is currently) using to obtain environmental observations during sea operations (both CMOD and CODE). This information is also very helpful for various past, present and future scientific programs involving surface drifters. It is planned to assimilate the drifter-inferred surface velocities into numerical models of the circulation in the Mediterranean to improve forecasting skills.

RELATED PROJECTS

1) This project is strongly related to current and future drifter programs in which I am involved (Black Sea, Tyrrhenian Sea, Adriatic Sea).

2) The drifter data collected will be used by Drs. A. Griffa and T. Ozgokmen to validate their theoretical studies of particle dispersion (ONR supported project).

PUBLICATIONS

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